Field emission characteristics of carbon nanotube emitters using screen-printing technique

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ABSTRACT

A carbon nanotube emitter with high uniformity, adhesion and emission current has been formed by screen printing. The raw carbon nanotubes (CNTs) chunk were crushed, purified, dispersed, mixed with organic additives and then screen-printed on Ag electrode. After burning out the organic additives under two thermal cycles, the surface of CNTs emitters were treated. The treated emitters showed a better emission characteristic than untreated emitters.

Keywords: carbon nanotubes, screen printing

1. INTRODUCTION

Carbon nanotubes have been attracting considerable attention because of their application potential for field emitters after the first observation by Iijima [1]. High chemical stability and high mechanical strength are advantageous for use in field emitters. Several results have been reported on the field emission not only from multi-walled nanotubes but also from single-walled nanotubes [2,3]. Recently, CRT-lighting element using MWNTs has been demonstrated by Ise Electronic Corporation [4] and Samsung showed a matrix addressable diode display [5]. From these typical papers, CNTs shows the potential in field emission display (FED).

The conventional FED formed by microtips. However, a major disadvantage of the microtip FED is the complicated processing steps such as a thin film deposition techniques and photolithographic methods which increase the manufacturing cost of FED. Therefore, utilizing CNTs emitters, the FED can be fabricated advantageously by a thick film printing technique at low fabrication cost and high fabrication efficiency.

In this paper, a screen printing process of fabricating CNTs emitters with high uniformity, high adhesion and high emission current has been studied.

2. EXPERIMENTS

The carbon nanotubes were fabricated by DC arc discharge. The chamber was maintained in He atmosphere with 500 mbar.

Arc constant DC current with 150 A and voltage with 20~24 V was applied to the anode and cathode separated with a gap about 2~3 mm.

To form the cathode plate, first, the cathode layer such as Ag was screen printed on a glass substrate. Secondary, on top of the cathode layer, CNTs layer was formed by a screen printing method. The homogeneous paste for screen printing was made by mixing organic components such as solvent, binder, plasticizer and dispersant with CNTs powders. Finally, the cathode and CNTs layer were heated to burn out the organic additives and melt the inorganic components such as frits and Ag.

The morphology and microstructures were observed by scanning electron microscopy (SEM). The particle size of CNTs powders were measured by Laser particle size analyzer. The decomposed temperature of CNTs and of organic additives of pastes were identified by thermalgravimetric analyzer (TGA). The field emission characteristics of CNTs layer by printing were measured by a diode technique using an electrometer. Anode plate with ITO layer and P22 or P15 phosphor was separated from cathode plate by 70 μm spacer.

3. RESULTS AND DISCUSSION

3.1. Purification and Dispersion

Usually, CNTs fabricated by arc discharge contains pure CNTs and other fillers. To increase the CNTs density of printed layer, the milled CNTs powders were purified by firing from 400°C to 600 °C in air atmosphere and the morphology of CNTs is shown in Fig. 1. From Fig. 1(b), the density of pure CNTs increase after the oxidation of other fillers. However, because of the physical and geometrical properties, the CNTs tend to form agglomeration. In Fig. 2, the weight loss of purified CNTs shows a drastically increase at 500 °C because of the decomposition of unstable fillers, and at 600 °C, few CNTs remain (about 6 wt%). From Fig. 1, whether purified CNTs or not, there are a lot of agglomeration. In order to improve the uniformity of emitters, the milled CNTs were treated by ultrasonics, acid solution or dispersants, and the particle size distribution is shown in Fig. 3. For ultrasonics treatment, the agglomerated CNTs (~20 μm) will be separated by screen to cause the non-homogeneous of paste. For acid solution and dispersants treatments, the negative ions adsorb on the open ends of CNTs and induce the electrostatic repulsion to make the CNTs powders dispersive well (~2 μm) in solution.

3.2 Firing and Microstructures

Fig. 4 shows the decomposed temperature of CNTs paste for screen printing. The first step of weight loss is solvent decomposition and the second step is binder, plasticizer and dispersant decomposition. From the results of Fig. 4, first, the CNTs layer was fired at 420°C in air to burn out clearly the organic and then fired at 450 °C to 550 °C to improve the adhesion between cathode layer (Ag) and CNTs layer.

Fig. 5 shows the microstructures in crosssection of CNTs and cathode layers. In Fig. 5(a), the green sample after drying shows the flatness upon CNTs layer resulted from the stress of blade, and a thin organic-rich film resulted from the evaporation of solvent. Because of above results in green, the surface of fired sample in Fig. 5(b) shows the poor outcrop of CNTs. From Fig. 5(a)(b), by the usual screen printing, it is not easy to produce a high density and perpendicular CNTs layer. Therefore, a surface treatment on CNTs layer is necessary and the result is shown in Fig. 5(c). The treatment such as sand blasting remove the stressed layer in surface of CNTs layer to disclose randomly arranged CNTs.

3.3 Characteristics of Field Emission

Fig. 6 shows the emission current density of CNTs layer with or without surface treatment. At the same electric field (E=5 V/μm), current density is 0.6 mA/cm^2 for untreated CNTs emitter and 12.5 mA/cm^2 for treated CNTs emitter. The improvement of current density is consistent with the surface reformation of CNTs layer. The correlative emission images of Fig. 6 are demonstrated in Fig. 7 (E=5 V/μm). From Fig. 7, surface treatment not only improves current density, but also increase the uniformity of emission.

4. CONCLUSION

Purified CNTs powders were achieved by firing above 500 °C. Milled and purified CNTs powders was dispersive about 2 μm by acid solution and dispersant treatments. The firing process was two-cycles profile to made a high adhesion CNTs layer. After firing, a fine structure in CNTs surface was formed by surface treatment. Surface treatment not only improves current density, but also increases the uniformity of emission. At 5 V/μm, current density is 12.5 mA/cm^2 for treated CNTs emitter

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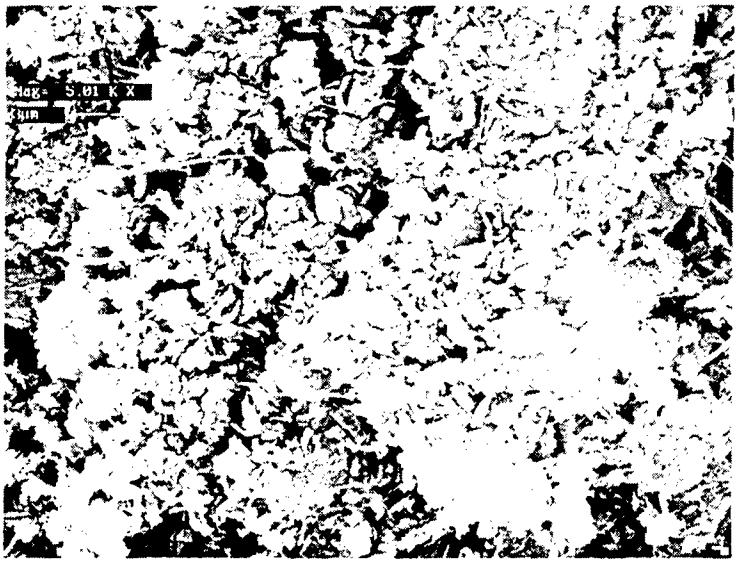
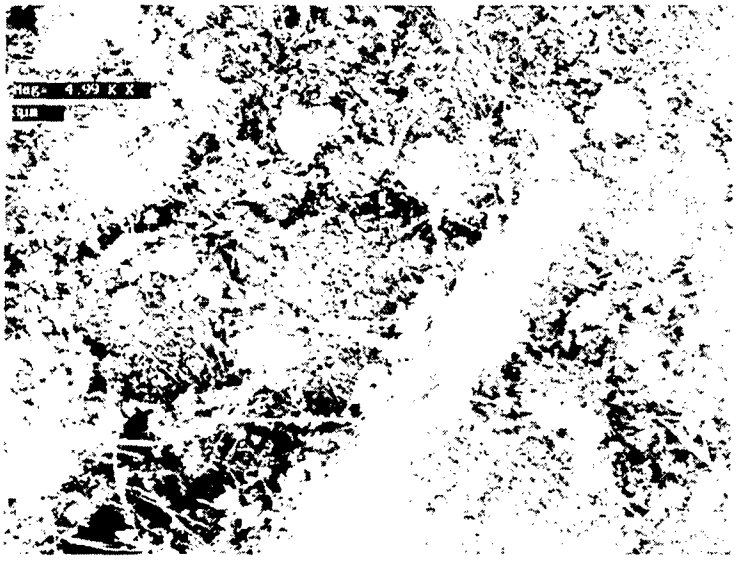


(a)



(b)

Fig. 1 SEM micrographs of (a) milled, and (b) milled and purified at 600 °C CNTs powder.

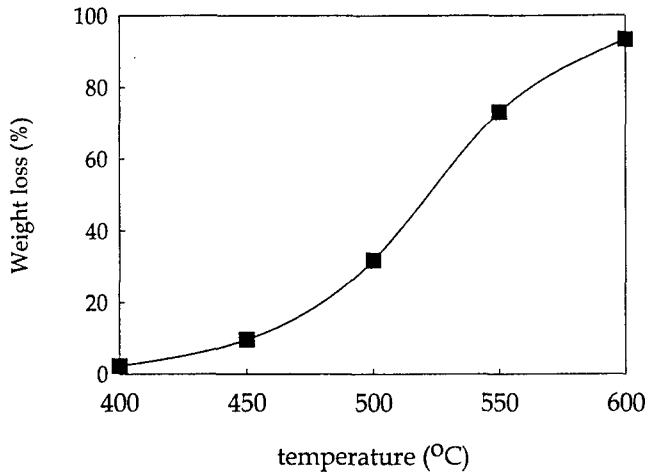


Fig. 2 Weight loss of purified CNTs powders from 400°C to 600 °C.

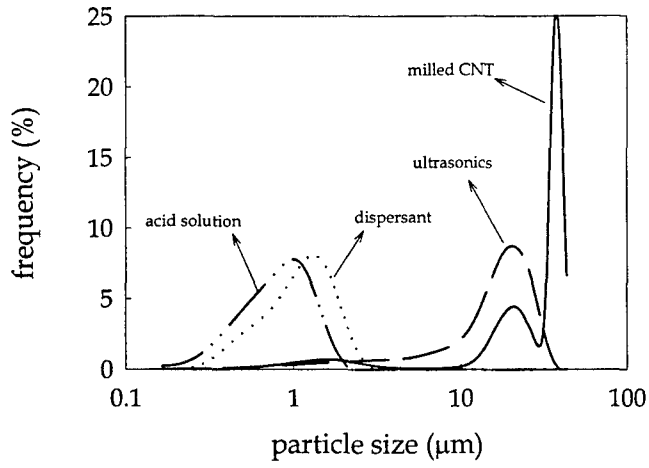


Fig. 3 Particle size distribution of milled and dispersed CNTs powders.

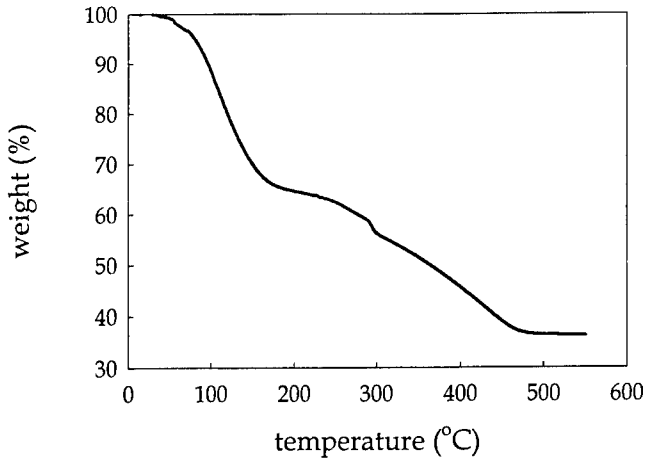
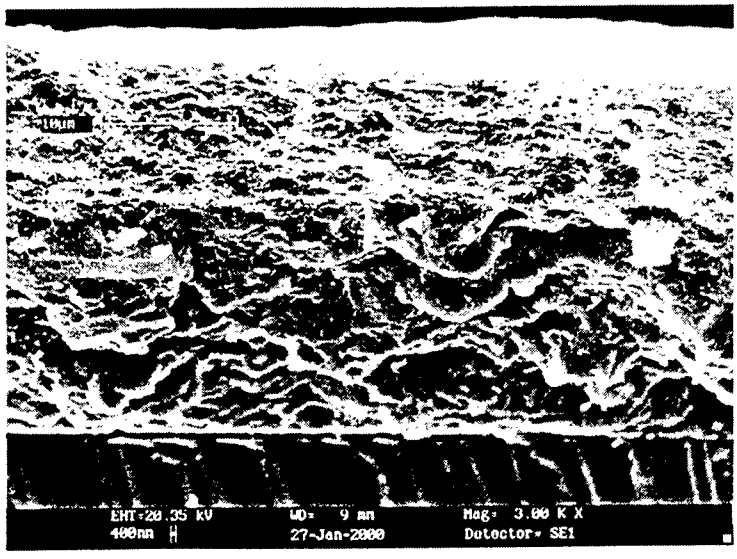
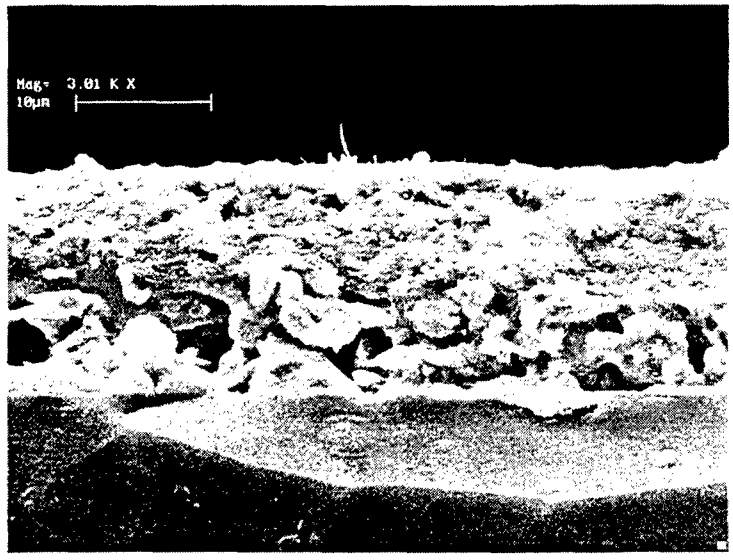


Fig. 4 TGA profile of CNTs paste.



(a)



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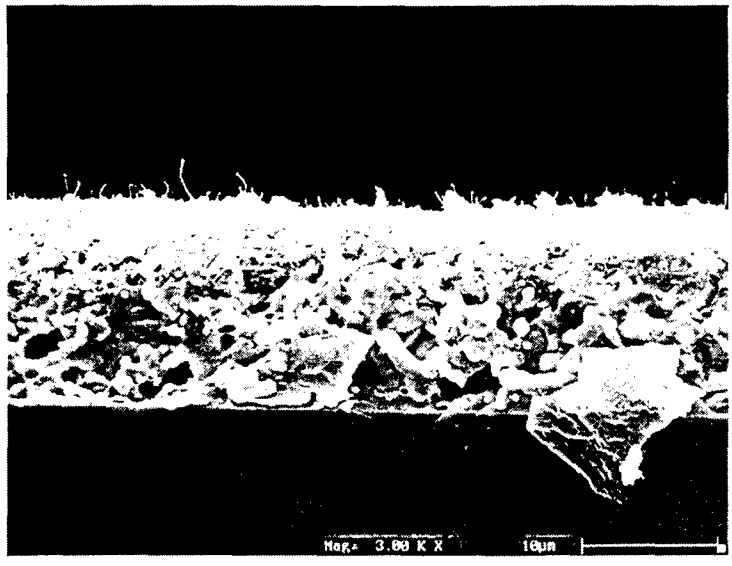


(c)

Fig. 5 Microstructures of CNTs and cathode layers for (a) green, (b) fired, and (c) fired and treated samples.

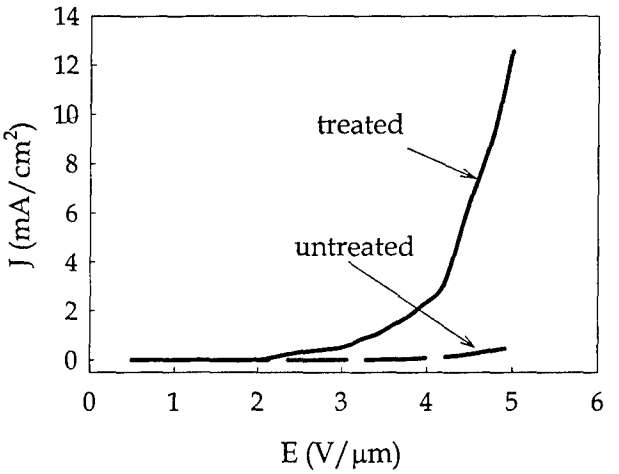
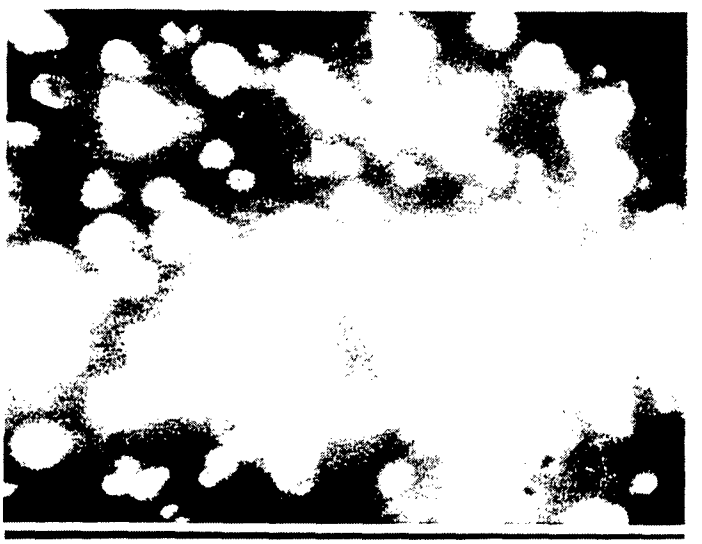
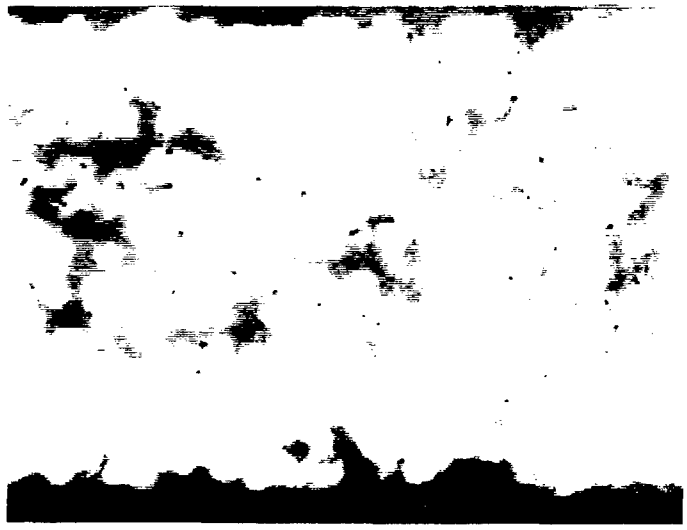


Fig. 6 Emission current density of CNTs layer before and after surface treatment.



(a)



(b)

Fig. 7 Emission images of CNTs layer (a) before, and (b) after surface treatment.